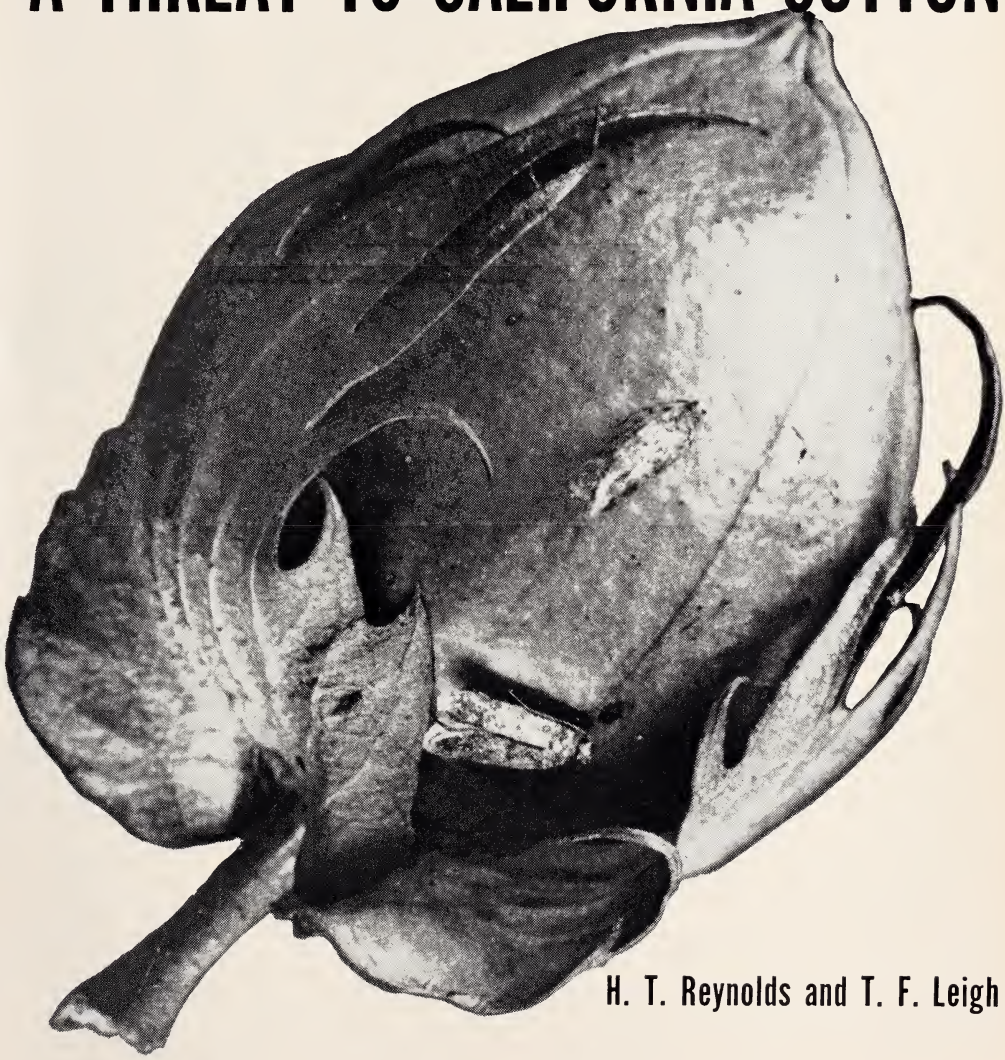
Division of Agricultural Sciences
UNIVERSITY OF CALIFORNIA

THE PINK BOLLWORM
A THREAT TO CALIFORNIA COTTON



H. T. Reynolds and T. F. Leigh

CALIFORNIA AGRICULTURAL
Experiment Station
Extension Service

CIRCULAR 544

This circular was designed to warn California farmers that if their cotton crops were not damaged by the pink cotton bollworm in 1966, such danger is now imminent—even in the San Joaquin Valley. Here is information on how this pest arrived in California, its life history and behavior, and the damage it does. Although information is given for the judicious use of insecticides, particular emphasis is placed on the following cultural and mechanical methods—preferred by far—to prevent and control infestations:

- a long, host-free period
- the right planting date and a short planting period
- early harvest and the best stalk-destruction methods
- efficient crop debris disposal
- good sanitation and ginning procedures

April 1967

THE AUTHORS:

H. T. Reynolds is Professor of Entomology and Entomologist in the Experiment Station, Riverside.

T. F. Leigh is Associate Entomologist in the Experiment Station, Davis, and stationed at the Shafter Field Station, Shafter.

THE PINK BOLLWORM—A THREAT TO CALIFORNIA COTTON

A SERIOUS threat to California's cotton crop now has become a reality. In 1965, populations of the pink bollworm—larval form of a small moth, *Pectinophora gossypiella* (Saunders)—exploded westward from Arizona into southeastern California; and during the 1966 season, many fields in Imperial, Riverside, San Bernardino, and San Diego counties suffered severe damage. In a few fields the entire late cotton set was lost, amounting to as much as 25 to 35 per cent of the yield. These desert areas with their warm, dry winter periods and longer production seasons apparently provide favorable conditions for infestation. The San Joaquin Valley has not yet been invaded, although it is likely only a matter of time.

The U. S. Department of Agriculture and state experiment stations recognized the threat of this pest shortly after its discovery in the United States and quickly initiated research programs. Much of this report is derived from publications[1] and personal contact with these agencies, as well as from observations and preliminary research in California.

The pink bollworm control program described here is based, in general, on good production practices. To some extent troublesome, it will require California growers to modify their current practices and plan ahead in order to comply with proposed regulations. Experiences in other areas has shown that area-wide cooperation can produce successful results if each farmer accepts responsibility not only for himself, but for the entire cotton industry, to see that his fields are not a primary source of infestation.

HOW IT GOT HERE

The pink bollworm is recognized as one of the most destructive cotton pests in the world. It was first reported as damaging cotton in India in 1843. Many mature larvae overwinter within the seed in a diapausing or inactive stage, and, in this condition, it has spread rapidly with seed shipments to most cotton-producing countries of the world. However, certain areas in the Western Hemisphere still remain free of the pest—such as Peru, Central America, parts of northwestern Mexico, the southeastern part of the United States—and, for the moment at least—the San Joaquin Valley of California.

This pest was first found in the United States in Texas in 1917. Rigid quarantine and cultural control programs were immediately imposed, and these greatly suppressed damage and slowed the spread of the pest. Infestations were first found in eastern Arizona in 1926. During the ensuing years it was apparently eradicated at least twice in central Arizona. The current infestation was found in the Gila Bend area in 1958. Eradication measures were applied again and apparently were progressing well until the effort broke down in 1962. Populations in Arizona built up rapidly to enormous numbers by 1964 and inevitably exploded westward into southeastern California in 1965. During the 1966 season a number of fields in southern cotton-producing counties suffered population explosions and severe damage. During that season, a few moths and larvae were found as far north as southeastern Kern County, but not in the San Joaquin Valley.

[1] See "References."

LIFE HISTORY AND BEHAVIOR

The adult of the pink bollworm is a small, inconspicuous moth about 3/8 inch long. When seen in the field, the wings are folded parallel to the body, giving an elongate, slender appearance. The coloring is somewhat variable, but in general is predominantly greyish-brown on head, thorax, appendages, and forewings. The forewing has areas of blackish scales, usually with two or more poorly-defined median spots, a blackish tip and a broader, blackish band before the tip. The tips of the wings are conspicuously fringed. The legs, antennae, and palps all bear a number of blackish rings. Frequently, field-collected specimens have been rubbed or damaged sufficiently to lose some of the identifying scale arrangements.

The moths hide under trash and clods of dirt and are seldom seen during the day. If disturbed, they fly short distances only to hide again. At night they fly about freely, mate, and lay eggs. Egg laying usually begins within two days after adult emergence, and each female moth may lay from 50 to 200 or more eggs over a period of about eight days. During warm weather a moth may live for about two weeks; this period is somewhat longer in the cooler spring or fall months.

The eggs of the pink bollworm are white and oval, and when magnified sufficiently, the surface appears finely wrinkled or sculptured. Because of the small size, approximately 1/50 inch long

Fig. 1. (above) Pink bollworm moths. (Actual size about 3/8 inch long.) See text for description. The specimen on right has lost much of the identifying scale arrangement.

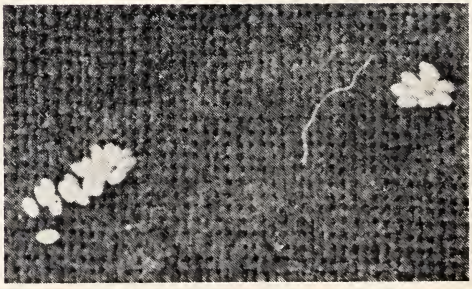


Fig. 2. (right) Two pink bollworm egg clusters on cloth. (3/4 actual size: •) (U.S.D.A. photo.)

Fig. 3. Mature pink bollworm larvae. (Actual size about 1/2 inch.) The dark transverse stripes are pink.

and 1/100 inch wide, they are seldom seen in the field without careful search. Hatching occurs four to five days after oviposition.

Eggs may be laid singly, but more often they are found in clusters. Early in the cotton-growing season, before squares appear, eggs are laid on sheltered parts of the plant. In the absence of fruiting forms, the small larvae are unable to survive. Thus, the term "suicidal emergence" is used when the moths emerge early in the season before suitable food is available on the cotton plant. Later in the season, virtually all the eggs are laid directly on fruiting forms, on both squares (considered suitable when slightly larger than a match head), and green bolls. Investigations suggest that about 85 per cent of the eggs are laid under the tight calyx which surrounds the base of the boll when 20-day-old (or larger) green bolls are available on the plant.

The larvae are tiny and glossy or creamy white with a prominent, dark-brown head, upon emerging from the egg. Fully grown larvae attain a length of about ½ inch; total time for larval development is about 10 to 14 days in warm weather. The typical color pattern of prominent pink, transverse bands on the back of each body segment appears in about the third stage of larval development.

(The pink scavenger caterpillar, *Sathrobrota rileyi*, superficially resembles the pink bollworm, but is only rarely found on cotton. It is a uniform pink, however, and is usually found in rotting bolls. It is not a primary pest.)

Fig. 4. Rosetted bloom caused by larvae webbing petal tips together before blooming. A nearly mature pinkish larva is inside.

Larval development is usually completed in the square or boll first entered. If the fruit is very small, however, it may shed, forcing the larva to seek other feeding sites or die. Those larvae feeding in squares frequently tie the petals of the developing buds together so that the flowers develop abnormally, forming a rosetted bloom (see photo). When the petals are pulled apart, a nearly mature, pinkish larva is usually found inside. Larvae emerging from eggs laid between the calyx and boll wall almost immediately enter the boll. The larvae are so small at this stage of development that the entrance holes are difficult to find. Larvae within bolls feed primarily on the developing seed, the number attacked depending upon boll size. In heavy infestations, several larvae of all sizes may be found in a single green boll.

When mature, the larva usually cuts a neat, round exit hole in the boll wall (see photo), drops to the ground, and pupates. Such exit holes are much smaller than those made by the ordinary cotton bollworm; and boll rots, commonly caused by the latter, often do not occur if the weather is dry.

The larvae complete development in

Fig. 5. Old (very small) exit holes cut by mature larvae leaving a green boll to pupate.

early and mid-season, pupate, and become adults about eight to 12 days later. These are frequently termed "short-cycle" larvae. Most of the larvae do not pupate late in the cotton season, but remain as mature larvae in a resting or hibernating condition (diapause) within a cocoon. Many of the diapausing larvae remain in the seed, and some are found in the lint in most of the United States. In Arizona and California, however, most larvae apparently leave the bolls to spin their overwintering cocoon on the ground in trash, lint, at the base of cotton stalks, or in soil cracks. Interestingly, very few actually burrow into the soil. Larvae that remain to diapause in the seed sometimes hollow out two seeds and may web them together, causing what is known as "double-seeds."

It is the diapausing or "long-cycle" larvae that survive over the winter to pupate and produce the first generation the following season.

Pupae size varies from about 1/4 to 3/8 inch long and about 1/10+ inch wide. After pupation, when dry, they are mahogany brown. The pupal surface is covered with small spines, which, under sufficient magnification, appear stubbly. The posterior terminates in a rather stout, dorsally directed hook. The small spines are significant, since they are largely absent on most other pupae of similar size. In summer, the pupal stage lasts about 10 days, but is considerably longer in cool weather.

Fig. 6. Pink bollworm pupae. (Actual size about 1/4 to 3/8 inch long.) (U.S.D.A. photo.)

Spring emergence and generations per year

Time of spring emergence varies to some extent depending upon weather conditions in different areas of the United States. In many areas, it begins about the middle of March, with peak emergences occurring in late May and early June. In Phoenix, Arizona, about 50 per cent of the emergence has taken place by the second week of May. A few adults do not emerge until midsummer, and some records show that a very small number do not emerge until the second year. Minor variations in this emergence pattern can be expected to occur in the various cotton-producing areas of California.

A complete generation, from adult to adult, may take as little as three to four weeks. Thus, under current production practices in areas such as the California desert valleys, as many as six to eight generations may occur in a season. In no other cotton production area in the United States, except for similar parts of Arizona, can so many generations be produced because of shorter seasons or early cotton plow-up. Thus the potential for the development of serious populations is enormous. Even low populations surviving the winter can result in seriously damaging numbers by the end of the production season.

Moth movement and population dispersal

As stated earlier, moths hide during the daylight hours and are active at night. In general, they cannot be considered strong fliers, despite the rapid spread through western cotton-producing areas.

1. Intra- and inter-field. As long as oviposition (egg-laying) sites are attractive, it is generally believed that the moths do not fly long distances for their reproductive activities. If moths emerge in

the spring from fields no longer planted to cotton, or if cotton is very small, they may fly in search of attractive fields. Also, there is some evidence that moths may search for better oviposition sites toward the end of the production season, if the fruiting forms are destroyed by larval activities or made otherwise unattractive.

2. Inter-area population dispersal. The shipment of infested cotton seed has generally provided the long population jumps into uninfested areas. Thus, the original infestation in Mexico is believed to have come from the shipment of infested seed from Egypt to Brazil, and subsequently to Mexico. Modern ginning equipment and oil mill plants, plus quarantines, have virtually eliminated infested seed as a source of new infestations, at least in the United States.

Although it cannot be considered a strong flier, prior experience in other areas, and more recently in Arizona and California, has shown that moths can move relatively long distances. In Texas, moths have been collected by aircraft at heights of up to 3,000 feet. Apparently the moths can become involved in ascending convection currents. When quite high, they drift with the prevailing wind for long distances. Some evidence indicates population jumps of as much as several hundred miles. The few moths and larvae collected as far north as southern Kern County, California, during the 1966 season provided ample evidence of wind dissemination.

Nature of damage (see photos)

Damage to cotton is caused by larval feeding activity in either squares or bolls. Square attack is most common in the absence of bolls. The anthers, style, and sometimes the ovary, are eaten in the squares and flowers. Although shedding results frequently, the larval population is sparse early in the season, and production is not seriously affected.

Fig. 7. Interior carpel walls with immature lint removed showing darker areas made by tunneling of small larvae. (U.S.D.A. photo.)

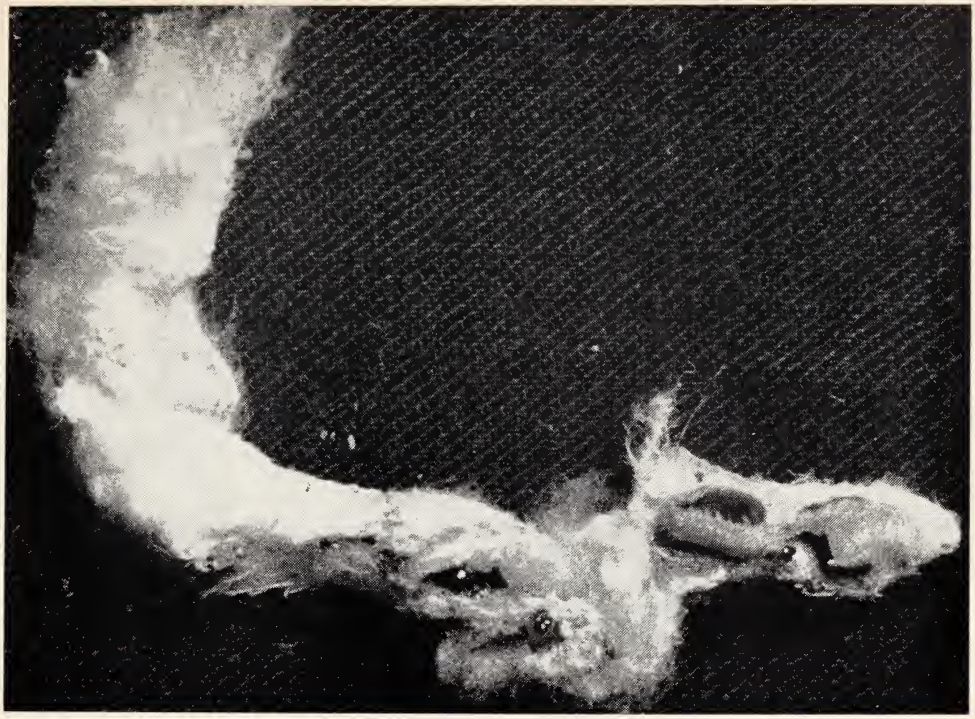


Fig. 8. Cotton seed hollowed out by pink bollworm larvae. Note larva in one seed and head of another protruding from the lowermost seed.

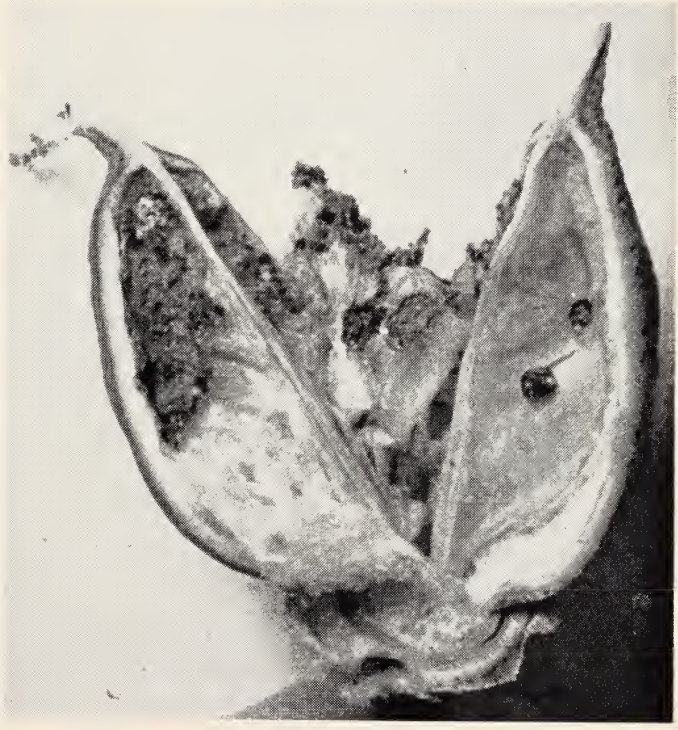


Fig. 9. Boll largely destroyed by pink bollworm larvae. Holes on right are made by larvae cutting into a second lock (removed) in search of undamaged seed. In low infestations larvae usually complete development in a single lock.

Fig. 10. Mature bolls showing various degrees of pink bollworm damage, *un*damaged bolls on bottom. Note partial fluffing on some locks in damaged bolls. (Texas A&M University photo.)

Fig. 11. Bolls completely destroyed by a number of pink bollworm larvae in each boll.

Bolls are the preferred site for oviposition and larval food. Upon hatching, the tiny larvae soon burrow or tunnel into the boll. The entrance hole is so small that it is difficult to find, but the tunnel or mine on the inner wall of the boll carpel is readily visible upon examination. Once inside the boll, the larvae burrow through the lint, searching out the seed. The main larval attack is on the developing seed. When one seed is destroyed, the larva tunnels through the developing lint in search of another. A larva usually completes its development in a single lock. One or two larvae per boll usually do not destroy an entire boll, but do inhibit fluffing of the lint in locks attacked. Thus, bolls are frequently found in infested fields with only one or two locks of normal-appearing cotton. In heavily infested fields, many bolls are so badly damaged that they are not picked at all.

Severe quality losses also occur when feeding larvae destroy large quantities of seed, and immature lint is cut, weakened, and stained as larvae burrow through. In humid areas the larvae exit holes provide entry for boll-rotting organisms.

Severe damage generally occurs late in the season when plants are heavily loaded with small and large green bolls, indicating that pink bollworm populations build up gradually. At this late date the crop is usually set, and it is too late for the plant to compensate for the loss by further fruiting. The top crop in the desert valleys of California amounts to about 25 to 35 per cent of the yield. A number of fields lost most of this top set in the 1966 season.

Host plants

Cotton is universally regarded as the major host of pink bollworm. The literature shows that many plants—all belonging to the plant family Malvaceae—can be infested by pink bollworm, but few are regarded as more than chance hosts.

Okra, a related plant, appears to be the only other significant host plant in California. It is grown in a few, small, commercial and backyard plantings. Although not considered to be as good a host as cotton, it is good enough to require the same cultural control regulations. Kenaf or Deccan hemp (*Hibiscus cannabinus*), grown in southern India, is also considered a good host for pink bollworm. This plant, however, was investigated and rejected as a potential fiber crop in Imperial Valley. Sometimes, larvae are found on hollyhock and ornamental *Hibiscus* buds and flowers, but their survival appears insignificant.

PREVENTION AND CONTROL

Cultural and mechanical methods prove best so far

At the present time and in the immediate future, research indicates that there is no alternative to good cultural and mechanical means to control pink bollworm. Insecticides can only be considered to be a supplement. But **successful control of pink bollworm demands uniform action and complete cooperation by everyone growing and handling cotton.**

The pink bollworm is the only major cotton pest that survives the winter in the mature larval stage. They can be found in old bolls and seed cotton left within the field, or in flimsy cocoons spun in trash or soil on or very near the ground surface. This "weak-link" in the life cycle of the pest can be broken by California growers if the following factors are considered:

1. The host-free period. The continuing practice of growing "stub" or ratoon cotton in Arizona which allows for no host-free period, is sometimes blamed for the present pink bollworm problem. This practice was fortunately discontinued in the desert areas of California, partly because of increasing "leaf crumple" prob-

Fig. 12. Cages near Blythe, California, to study overwintering survival of hibernating larvae.

lems (a cotton plant virus transmitted by a whitefly).

A host-free period is absolutely imperative to control pink bollworm, although it must be admitted that how long that period should be in California has not been determined. Current regulations call for a two and one-half to three-month cotton-free period, but most entomologists experienced in pink bollworm control maintain this is not long enough. It is also entirely possible that in desert areas, a small amount of top crop must be sacrificed in order to give sufficient host-free time. Research underway and experience over the next season or two should provide reasonably accurate information on the necessary time period (see photo).

In the spring, growers should be watchful to destroy volunteer cotton plants along roadsides and in fields that can support squares before they appear on planted cotton. In fields planted to barley following cotton, 2,4-D application for weed control should destroy volunteer cotton plants.

2. Uniform short planting period. Cotton planting should be delayed until the latest practical date, then completed as quickly as possible, primarily to **take maximum advantage of suicidal emergence** of the moths in the spring. In the absence of suitable egg-laying sites (slightly larger than match-head-size squares, bolls, and the like), the moths cannot lay eggs from which larvae can survive. In Phoenix, Arizona, an area nearly comparable with California desert areas, an average of about 40 per cent of the overwintering larvae had pupated and emerged as moths by the first week in May. Since it takes about 40 to 60 days from planting to first squares in the California desert, a good percentage of moths will die before larvae from their eggs can survive, if cotton is planted no earlier than March 15. Earlier planting may attract a high percentage of early emerging moths and serve as a primary source of later infestations over a large area. Planting in the San Joaquin Valley no earlier than April 1 is suggested, although it is not yet possible to estimate what pattern suicidal emergence might take in this area.

If all cotton is planted as soon as possible after the approved planting date, most fields will mature with reasonable uniformity. Thus, no extremely late-maturing fields, heavily laden with green bolls, will be available for an additional generation of the pest and still greater populations.

Fig. 13. Demonstration of a flail-type shredder (Brady All-Crop Pulverator) in operation. (U.S.D.A. photo.)

3. The cotton-growing period. The pink bollworm builds up over the season and reaches its maximum potential for damage in the late season. Agronomic practices should be used that produce a maximum bottom and middle set of cotton which will mature before it can be seriously attacked.

4. Early harvest and destruction of stalks. Cotton should be defoliated and harvested at the earliest date compatible with good production. Defoliation drastically reduces attraction of the field to the moths. Harvest and stalk destruction stops reproduction and reduces the number of overwintering larvae. **The time of stalk destruction and the ensuing cultural procedures until cotton is planted the following spring are the most critical steps in reducing overwintering pink bollworm populations.**

It is advisable to have shredders in the field before picking or scrapping is completed, since shredding destroys vast numbers of larvae and stops further reproduction and generations of the pest. Scrapping undoubtedly removes large numbers of overwintering larvae from the field, including many on the soil surface in overwintering cocoons in seed and lint.

Rotary shredder. At present most growers use rotary shredders for destroying stalks. These break up stalks and plant debris for easy plowing. Depending upon speed of operation, the rotary shredders kill from about 40 to 60 per cent of the larvae in bolls left on the plant. In Texas, such kills were obtained at a ground speed of 1.7 mph and a shaft speed of 810 rpm. Higher ground speeds reduced larval kills, but shaft speeds should be as high as practical.

Flail shredder (*see photos*). The flail shredder is more effective than the rotary type, but few, if any, are being used at present in California. Research in Texas indicated that the flail-type shredder kills from 80 to 90 per cent of the larvae and cuts the stalks and bolls into smaller pieces than the rotary-type, ensuring better coverage and decomposition of the crop debris. It also picks up much seed cotton from the soil surface and cracks the seed, killing many worms. This type of shredder has been most effective when operated at a ground speed of 1.7 mph and with a shaft speed of 1,620 rpm. While it requires more power to operate than the rotary-type, the greater efficiency of the flail-type shredder should re-

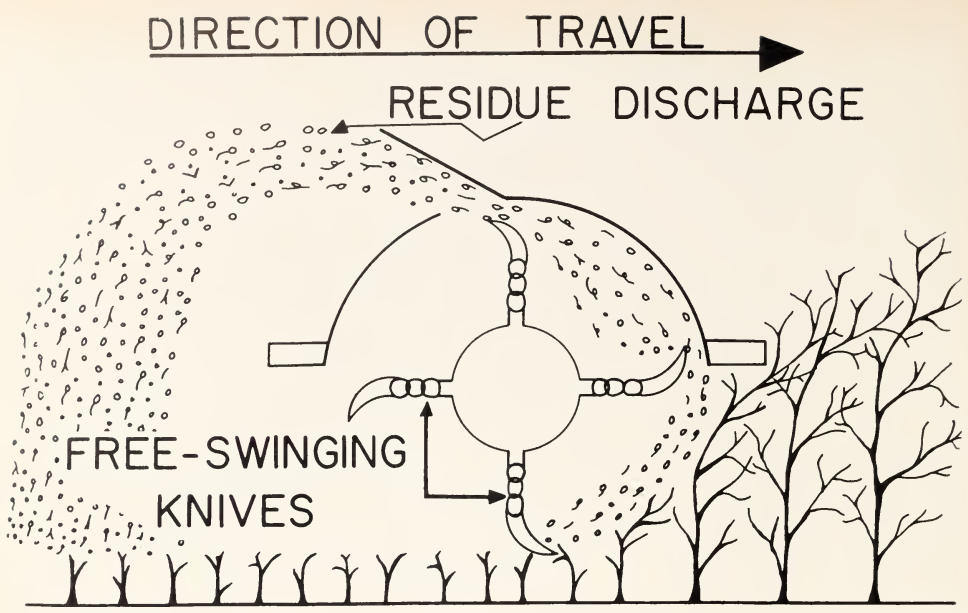


Fig. 14. Schematic drawing showing the principal parts of a flail-type cotton stalk shredder equipped with a horizontal shaft and vertical rotating, free-swinging knives (after Texas Agr. Exp. Sta. Report 2095).

ceive serious consideration by California growers.

Rolling stalk cutter. This type of equipment, although used very little, is inferior and should be abandoned in pink bollworm-infested areas.

5. Plowed-under crop debris and flood irrigation. Plow under crop debris with a moldboard-type plow as soon as possible. Do not wait for the plow-up date. Tractor speed should be carefuly regulated so that the soil surface is turned completely over; driving too slowly or too fast will not accomplish this objective. Growers are usually advised to turn debris under at least six inches. Ten to 12 inches or even deeper is much preferred, however, since greater depths are known to give much better pink bollworm kill. In general, survival is higher in heavy soils than in lighter soils, perhaps due to deep soil cracking and/or insufficient winter moisture.

Disking and double disking do not appear to be entirely satisfactory, according to observations made at the end of the 1966 season. With this method the seed cotton and bolls are stratified through the soil and entirely too many are left on the surface. In many heavily infested fields, surviving overwintering larvae were readily found on or just below the soil surface—the best place for winter survival.

Flood irrigation is a primary requisite for good winter kill in regions with low winter rainfall, such as most California cotton-producing areas. Flooding also accelerates debris decay which speeds kill of the larvae in bolls and seed. In the generally arid conditions of California, plowing under the overwintering larvae without irrigation is not successful. The soil should be kept as wet as possible as long as possible. It is not known at present whether more than a single irrigation is required, but research should provide the answer relatively soon.

A broadcast application of nitrogen just prior to plowing may accelerate decay of crop debris.

6. Rotation and covercrops. Research has demonstrated that overwintering pest survival is clearly reduced by planting a winter crop immediately after plowing under the cotton debris. This provides rotation out of cotton for a season and the

necessary irrigation to grow the winter barley or other crops, which speeds rotting of the cotton debris.

Use of insecticides

Three insecticides are generally recommended for reducing pink bollworm populations in severely infested states. These are carbaryl (Sevin®), DDT and Guthion®. Since larvae are inaccessible within the bolls, applications of insecticides kill comparatively few. Thus, the relatively successful use of insecticides is predicated largely upon killing the moths to reduce oviposition. In most areas in the United States, repeated applications at five-day or weekly intervals are necessary to repress damage.

In Texas, the need for applying chemicals is determined according to the 1966 Texas Guide for Controlling Cotton Insects—as follows:

"Begin pink bollworm counts after cotton has been blooming for at least five days. Select five representative locations in the field, step off 300 feet of row and count the number of rosetted blooms. Add the total number of rosetted blooms from these five locations and multiply by 10 to obtain the number of worms per acre. When approximately 350 or more worms per acre are found, begin treatment immediately.

"When less than 350 worms per acre are found, make boll inspections as soon as the first bolls are four weeks old. Continue inspections weekly. Walk diagonally across the field and collect at least 100 bolls (two-thirds grown or larger). Crack the bolls and examine the inside of the hull for tunnels made by small worms. Start treatment when 10 to 15 per cent of the bolls are infested. Continue treatment until 70 per cent are open."

In several areas, carbaryl is recommended at the rate of 1.5 to 2 pounds per acre, DDT at 1.5 to 2.0, and Guthion at about 0.5 to 0.75. The latter compound is usually incorporated at lower rates with DDT to restrain populations of other pests, particularly bollworm. In most cotton-producing areas of California, DDT cannot be used because of possible contamination of alfalfa and other neighboring crops. Also, resistance of pink bollworms to DDT has been reported in several areas, though not in the west.

It should be said here that the prospect of repeated applications of insecticides such as these on California cotton is viewed with great concern. Not only is such insecticidal control of pink bollworm imperfect, but production costs will increase greatly. Other pest species, such as lygus bugs could develop resistance faster.

Furthermore, in the desert valleys a great deal of progress has been made in pest control by increasingly careful evaluation of chemical control needs and the use of reasonably selective chemicals. Through this approach, several pests of a decade ago are no longer severe. For example, cabbage loopers and leafrollers are no longer problems; and pests such as the cotton leaf perforator, salt marsh caterpiller, spider mites and bollworm are no longer nearly as severe as they once were, with insecticidal control required in comparately few fields in recent years. If heavy reliance on the insecticides currently recommended for pink bollworm is necessary, the progress in control of other pests could be lost. Cultural controls should be made as effective as possible, even if it means some sacrifice in late boll set.

Sanitation practices and ginning

Trailers must be covered and pulled at not more than 20 mph when carrying seed cotton to the gin. Seed cotton left along the roadside is a potential overwintering source of larvae.

Many pink bollworm larvae are carried to the gin in seed cotton, which is particularly abundant in material from stripping or scrapping. More than 99 per cent of these larvae are killed, however, in a modern gin (see photo). Due to the mortality of larvae in the ginning operation, as well as in the oil processing and treatment of planting seed, survival in seed is not significant in infested areas.

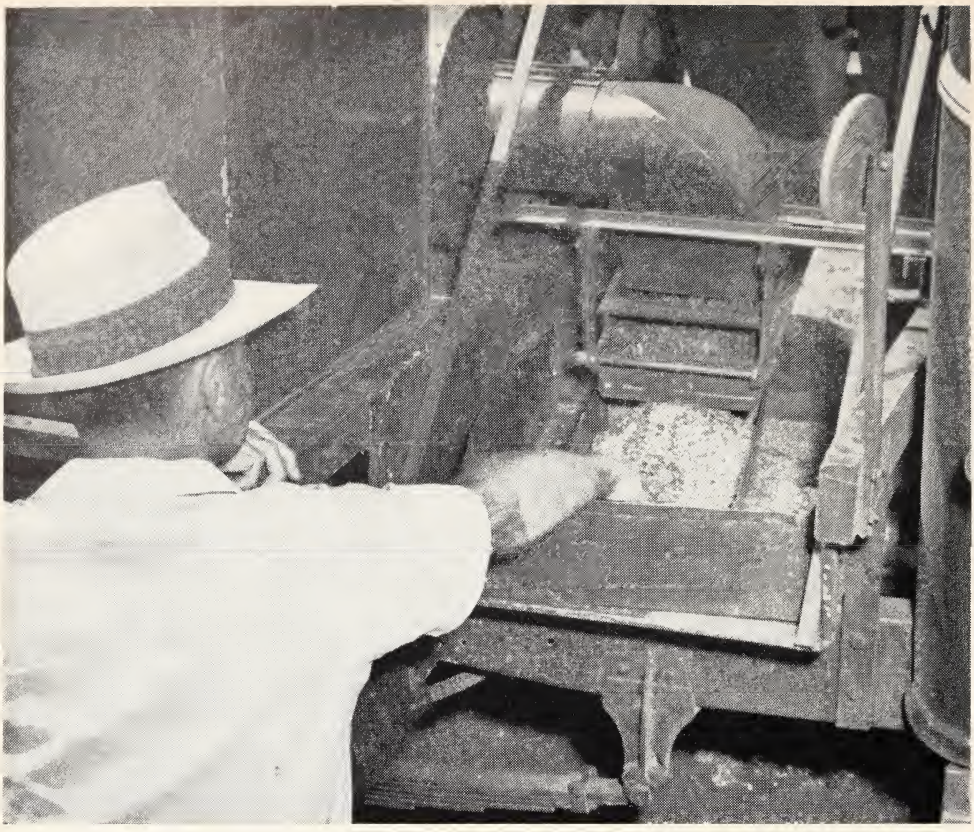


Fig. 15. Examination for pink bollworms in gin trash after running through a separating machine. (U.S.D.A. photo.)

The greatest potential source of infestation from the gin is the seed cotton that may be spilled to overwinter on the premises. This seed cotton on the gin site should be ginned, fumigated, or destroyed to prevent possible infestation.

Ginning efficiency notwithstanding, any seed that is to be shipped to uninfested areas must be fumigated with methyl bromide or treated with heat to kill larvae. To comply with regulations concerning shipment of cotton seed, contact local regulatory officials for the proper procedure and certification.

Gin trash may be burned, but most modern gins are equipped with high-speed fans which destroy larvae in the trash. If so, gin trash can usually be spread over fields. But if there is any question, contact local regulatory officials for clearance.

Growers should check on the origin of each item of harvesting equipment, i.e., pickers, trailers, scrappers, and the like, before it enters a field. If it has come from a quarantine area, a certificate of treatment is required. If it does not have a certificate and is from an area under quarantine, notify the county Agricultural Commissioner. The same applies for hand-picking crews with their own picking sacks.

More biological control studies needed

Many parasites, a few predators, and several disease organisms attack the pink bollworm in various parts of the world. Introductions of *exotic* species have been attempted in several countries, including the United States. The releases in this country were not made under conditions

suitable for successful establishment, thus their potential efficiency has not been evaluated. Finally, the potential role of *native* parasites and predators has not been sufficiently studied.

Further studies, including the search for beneficial exotic species, are greatly needed not only because of the serious nature of pink bollworm damage, but because of the disadvantages associated with repeated insecticide applications.

U.S.D.A. entomologists have found that the female moth, when ready to mate, attracts the males with a chemical called a sex-lure or pheromone. Small quantities extracted from virgin females have been available for limited research and survey purposes. Progress is being made in synthesis of this chemical in the laboratory. Some progress has also been made by entomologists at the U.S.D.A. Pink Bollworm Laboratory at Brownsville, Texas, who are investigating the possibility of using the "sterile-male" technique which has been used for screw-worm and certain fruit flies.

References

Adkisson, P. L.
1961. Effect of larval diet on the seasonal occurrence of diapause in the pink bollworm. Jour. Econ. Ent. **54**(6):1107–12.

Adkisson, P. L., J. R. Brazzel, and J. C. Gaines
1963. Yield and quality losses resulting from pink bollworm damage to cotton. Texas Agr. Exp. Sta. **MP-632.** 8 pp.

Adkisson, P. L., and J. C. Gaines
1960. Pink bollworm control as related to the total cotton insect control program of central Texas. Texas Agr. Exp. Sta. **MP-444.** 7 pp.

Adkisson, P. L., O. T. Robertson, and L. C. Fife
1962. Planting date as a factor involved in pink bollworm control. Texas Agr. Exp. Sta. **MP-579**:16–20.

Adkisson, P. L., L. H. Wilkes, and S. P. Johnson
1958. Chemical, cultural and mechanical control of the pink bollworm. Texas Agr. Exp. Sta. Bul. **920.** 16 pp.

Anonymous
1965. Ways to fight the pink bollworm. Texas Agr. Exp. Sta. **L-219.** 8 pp.
1966. Texas guide for controlling cotton insects. Texas Agr. Exp. Sta. **L-218.**

Brazzel, J. R., and D. F. Martin
1956. Resistance of cotton to pink bollworm damage. Texas Agr. Exp. Sta. Bul. **843.** 20 pp.
1959. Winter survival and time of emergence of diapausing pink bollworms in central Texas. Jour. Econ. Ent. **52**(2):305–08.

Bull, D. L., and P. L. Adkisson
1960. Certain factors influencing diapause in the pink bollworm, *Pectinophora gossypiella.* Jour. Econ. Ent. **53**(5):793–98.

Chapman, A. J., and L. B. Coffin
1964. Pink bollworm resistance to DDT in the Laguna area of Mexico. Jour. Econ. Ent. **57**(1):148–50.

Chapman, A. J., L. W. Noble, O. T. Robertson, and L. C. Fife
1960. Survival of the pink bollworm under various cultural and climatic conditions. U.S.D.A. Agr. Res. Adm., Prod. Res. Rept. No. **34.**

Chapman, A. J., O. T. Robertson, and L. W. Noble
1961. Evaluation of stalk shredders and cutters for pink bollworm control. Jour. Econ. Ent. **54**(4):791–92.

Fife, L. C., O. T. Robertson, and H. M. Graham
1963. Winter carry-over of the pink bollworm under various cultural practices in central Texas. Jour. Econ. Ent. **56**(2):172–75.

Lukefahr, M. J., L. W. Noble, and D. F. Martin
1964. Factors inducing diapause in the pink bollworm. U.S.D.A. Agr. Res. Adm. Tech. Bul. **1304.**

Martin, D. F., and R. D. Lewis, Editors
1962. A summary of recent research basic to the cultural control of pink bollworm. Special Rept. of Tech. Comm. of Regional Research Project **S–37.** Agr. Exp. Sta. of Arizona, Arkansas, Louisiana, Puerto Rico, Texas, and U.S.D.A. **MP-579.** 28 pp.

McDonald, R. E., and U. C. Loftin
1935. Dispersal of the pink bollworm by flight or wind carriage of the moths. Jour. Econ. Ent. **28**(5):745–55.

McGarr, R. L., A. J. Chapman, and D. F. Martin
1965. Field tests with several insecticides for control of the pink bollworm, boll weevil, and bollworm. Jour. Econ. Ent. **58**(4):693–94.

Ohlendorf, W.
1926. Studies of the pink bollworm in Mexico. U.S.D.A. Bul. **1374.** 64 pp.

Owen, W. L., and S. L. Calhoun
1932. Biology of the pink bollworm at Presidio, Texas. Jour. Econ. Ent. **25**(4):746–51.

Pearson, E. O.
1958. The insect pests of cotton in tropical Africa. The Empire Cotton Growing Corporation *and* The Commonwealth Institute of Entomology 56, Queen's Gate, London, S.W. 1. pp. 164–200.

Richmond, C. A., and E. W. Clark
1965. Effects of soil type, temperature and moisture on pink bollworm larvae and pupae buried under laboratory conditions. U.S.D.A. Tech. Bul. **1347**:1–29.

Tsao, C. H., and W. L. Lowry
1963. Insecticidal control of first-instar pink bollworm larvae and observations of their dispersal on cotton plants. Jour. Econ. Ent. **56**(3):370–72.

Wene, G. P., and L. W. Sheets
1966. A summary report of pink bollworm research in 1965. Arizona Agr. Exp. Sta. Rept. **239.** 23 pp.

Wene, G. P., L. W. Sheets, and H. E. Woodruff
1961. Emergence of overwintering pink bollworm in Arizona. Jour. Econ. Ent. **54**(1):192–93.

Wene, G. P., L. W. Sheets, H. E. Woodruff, I. Pearson, and L. A. Carruth
1965. Winter survival of the pink bollworm in Arizona. Univ. of Arizona Agr. Exp. Sta. Tech. Bul. **170**:1–23.

Wilkes, L. H., P. L. Adkisson, and B. J. Cochran
1959. Stalk shredder tests for pink bollworm control, 1958. Texas Agr. Exp. Sta. Progress Rept. **2095.** 2 pp.

To simplify the information, it is sometimes necessary to use trade names of products or equipment. No endorsement of named products is intended nor is criticism implied of similar products not mentioned.

WARNING ON PESTICIDE RESIDUES

These recommendations for pest control are based on the best information currently available for each pesticide listed. Treatments based upon these recommendations should not leave residues that will exceed the tolerance established for any particular chemical. To avoid excessive residues, follow directions carefully with respect to dosage levels, number of applications, and minimum interval between application and harvest.

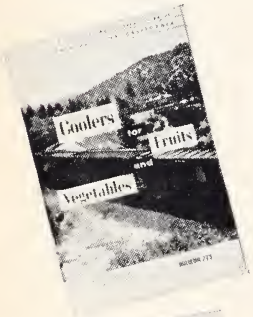
THE GROWER IS LEGALLY RESPONSIBLE for residues on his crops as well as for problems caused by drift from his property to other properties or crops.

15*m*-4,'67(H993s)P.A.V.

THE GOOD EARTH

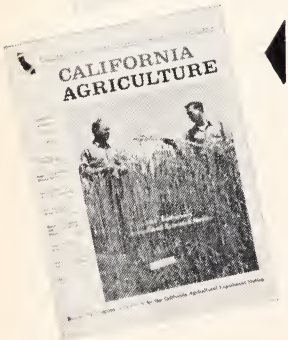
. . . is the abundant earth. To achieve it, vast knowledge is needed now—and more will be required as expanding populations continue to make even greater demands upon the earth's resources.

How are scientists, researchers, and agriculturists developing and implementing knowledge which will make the good earth flourish for future generations? In part, the answer will be found in the many publications put out by the University of California's Division of Agricultural Sciences. Among these publications are:



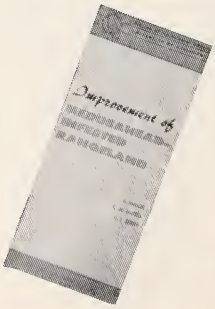
the BULLETIN series . . . designed for an audience of scientists, and for informed laymen interested in new research.

the CIRCULAR series . . . intended for a popular audience, and offering extensive discussions of some phase of an agricultural operation



CALIFORNIA AGRICULTURE . . . a monthly magazine describing latest research in the Division of Agricultural Science, and designed for researchers, informed farmers, and agri-businessmen

LEAFLETS . . . these are short circulars designed to answer one or a few questions for the home-grower or farmer without giving detailed background information



For a catalog of publications, write Agricultural Publications, 207 University Hall, University of California, Berkeley, Calif. 94720